(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 154 676 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 158(3) EPC

(43) Date of publication:
14.11.2001 Bulletin 2001/46

(21) Application number: **00977858.0**

(22) Date of filing: **22.11.2000**

(51) Int Cl.[7]: **H05B 33/12**, H05B 33/24, H05B 33/14, H01L 33/00, G02B 5/28

(86) International application number:
PCT/JP00/08233

(87) International publication number:
WO 01/39554 (31.05.2001 Gazette 2001/22)

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR

(30) Priority: **22.11.1999 JP 33080599**
23.08.2000 JP 2000251996

(71) Applicant: **Sony Corporation**
Tokyo 141-0001 (JP)

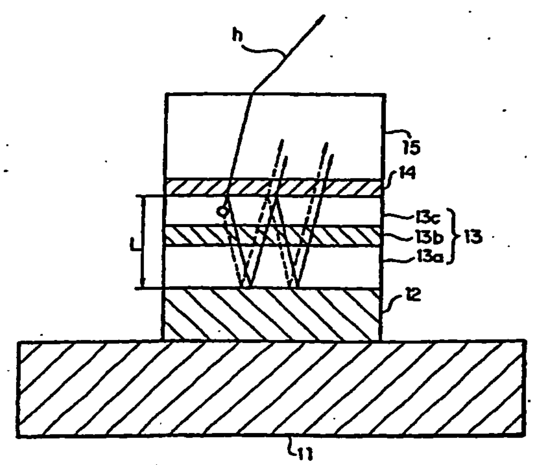
(72) Inventors:
- **YAMADA, Jiro c/o Sony Corporation**
  Shinagawa-ku, Tokyo 141-0001 (JP)
- **SASAOKA, Tatsuya c/o Sony Corporation**
  Shinagawa-ku, Tokyo 141-0001 (JP)
- **HIRANO, Takashi c/o Sony Corporation**
  Shinagawa-ku, Tokyo 141-0001 (JP)

(74) Representative: **Müller, Frithjof E., Dipl.-Ing.**
Patentanwälte
MÜLLER & HOFFMANN,
Innere Wiener Strasse 17
81667 München (DE)

(54) **DISPLAY DEVICE**

(57) In an organic EL device having a first electrode of a light reflective material, organic layer including an organic light emitting layer, semitransparent reflection layer, and second electrode of a transparent material that are stacked sequentially, and so configured that the organic layer functions as a cavity portion of a cavity structure, light that resonates in a certain spectral width (wavelength λ) is extracted by so configuring that optical path length L becomes minimum in a range satisfying $(2L)/\lambda + \Phi(2\Pi) = m$ (m is an integer) where the phase shift produced in light generated in the organic light emitting layer when reflected by opposite ends of the cavity portion is Φ radians, L is optical path length of the cavity portion, and λ is the peak wavelength of the spectrum of part of light to be extracted.

Fig. 4



EP 1 154 676 A1

Printed by Jouve, 75001 PARIS (FR)

[0012] A further object of the invention is to provide a spontaneous emission type display device that can maintain a sufficient color reproduction range over a wide view angle and can improve the contrast by reducing reflection of external light without inviting a decrease in luminance.

Disclosure of Invention

[0013] To accomplish the above objects, according to the invention, there are provided display devices each including a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material such that at least one of the second electrode and the light emitting layer serves as a cavity portion of a cavity structure, in which the cavity portion has any of the configurations shown below.

[0014] In the first display device, when the phase shift produced in light generated in the light emitting layer when reflected by opposite ends of the cavity portion is Φ radians, L is optical path length of the cavity portion, and λ is the peak wavelength of the spectrum of part of light to be extracted, optical path length L of the cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)} \tag{1}$$

[0015] In the first display device having the above-summarized configuration, since the optical path length L of the cavity portion satisfies Equation (1), multiple interference of light near the wavelength λ occurs in the cavity portion. Additionally, since the optical path length L of the cavity portion is controlled to be the positive minimum value in the range satisfying Equation (1), spectrum of the extracted light is maintained in the widest width in the range inducing multiple interference of the light with the wavelength λ. As a result, in the display device, while the spectrum of the extracted light keeps a certain width, the peak intensity is enhanced by multiple interference. Therefore, the display device exhibits only a small shifting amount of the wavelength λ even when viewed from different view angles and provides an improved color purity in a wider view angle range.

[0016] In the second display device, when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the following equation (3) which is made by adding 4 to the integer m1 that is one of integers m satisfying the following equation (2), with which L takes a positive minimum value.

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)} \tag{2}$$

$$(2L')/\lambda \pm \Phi/(2\Pi) = m1 + 4 \tag{3}$$

[0017] In the second display device having the above-summarized configuration, multiple interference occurs in light with wavelengths corresponding to red (R), green (G) and blue (B) in the cavity portion. As a result, peak intensity of spectrum of each emitted light can be enhanced without setting optical path length L' of the cavity portion specifically for each color. Therefore, a common optical path length L' of the cavity portion can be used in all display devices corresponding to respective emitted colors.

[0018] In the third display device, when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the following equation (5) which is made by adding an integer not smaller than 10 to the integer m1 that is one of integers m satisfying the following equation (4), with which L takes a positive minimum value.

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)} \tag{4}$$

$$(2L')/\lambda + \Phi/(2\Pi) = m1 + q \tag{5}$$

[0019] In this display device, multiple interference occurs among a number of light components with different wavelengths in each of the ranges of red (R), green (G) and blue (B) in the cavity portion. As a result, in a color display apparatus using such display devices, a common optical path length L' of the cavity portion can be used in all display

shows a simulation of spectrums to show the filtering property of the organic layer itself in the conventional organic EL device; Fig. 10 is a schematic diagram that shows dependency of the organic EL device (G emission) according to the first embodiment of the invention upon the view angle; Fig. 11 is a schematic diagram that shows dependency of the conventional organic EL device (G emission) upon the view angle; Fig. 12 is a schematic diagram that shows chromaticity coordinates of the organic EL device according to the first embodiment of the invention and a comparative example; Fig. 13 is a cross-sectional view that shows a central part of an organic EL device according to the second embodiment of the invention; Fig. 14 is a schematic diagram that shows a simulation of spectrums to show the filtering property of the organic layer itself in the organic EL device according to the second embodiment of the invention; Fig. 15 is a cross-sectional view that shows a central part of an organic EL device according to the third embodiment of the invention; Fig. 16 is a schematic diagram that shows a simulation of spectrums to show the filtering property of the organic layer itself in the organic EL device according to the third embodiment of the invention; Fig. 17 is a schematic diagram that shows a simulation of light spectrums extracted from the organic EL device (G emission) according to the third embodiment of the invention; Fig. 18 is a cross-sectional view that shows a central part of a further organic EL device to which the invention is applied; Fig. 19 is a cross-sectional view that shows a central part of an organic EL device according to the fourth embodiment of the invention; Fig. 20 is a schematic diagram that shows a simulation of spectrums to show the external light reflection property of the organic EL device according to the fourth embodiment of the invention, when using no color filter; Fig. 21 is a schematic diagram that shows spectrums representing transmission properties of different color filters used in the organic EL device according to the fourth embodiment of the invention; Fig. 22 is a schematic diagram that shows a simulation of spectrums to show the external light reflection property of the organic EL device according to the fourth embodiment of the invention; and Fig. 23 is a cross-sectional view that shows an alternative configuration of the central part of the organic EL device according to the fourth embodiment.

Best Mode for Carrying Out the Invention

[0028] Explained below are some embodiments of the invention with reference to the drawings. Here are explained embodiments of display device as applying the invention to organic EL devices.

[0029] Fig. 4 shows an organic EL device according to the first embodiment of the invention. The organic EL device shown in Fig. 4 is a so-called top surface emission type organic EL device, and includes a first electrode 12, organic layer 13, semitransparent reflection layer 14 and second electrode 15 stacked on a substrate 11 sequentially from bottom to top.

[0030] The substrate 11 is, for example, a transparent glass substrate, semiconductor substrate, or the like, and may be flexible.

[0031] The first electrode 12 is used as an anode electrode that functions as a reflection layer as well, and it is made of a light reflective material such as platinum (Pt), gold (Au), chromium (Cr), tungsten (W), or the like. The first electrode 12 preferably has a thickness in the range from 100 nm to 300 nm.

[0032] The organic layer 13 is made by stacking, for example, a buffer layer 13a, hole transport layer 13b and organic light emitting layer 13c also functioning as an electron transport layer, sequentially from bottom. The electron transport layer may be provided separately from the organic light emitting layer 13c. The buffer layer 13a is a layer for preventing leakage, and may be made of, for example, m-MTDATA [4, 4', 4"-tris (3-methylphenylphenylamino) triphenylamine], 2-TNATA [4, 4', 4"-tris (2-naphtylphenylamino) triphenylamine], or the like. The buffer layer 13a may be omitted if leakage is in an acceptable level. The hole transport layer 13b may be made of, for example, α-NPD [N, N'-di (1-naphthyl)-N, n'-diphenyl-[1, 1'-biphenyl]-4, 4'-diamine]. The organic light emitting layer 13c is made of different light emitting materials having emission colors of red (R), green (G) and blue (B). For example, as the light emitting material having the G emission color, Alq3 (tris-quinolinolaluminum complex) may be used.

[0033] These layers forming the organic layer 13 are preferably in specific thickness ranges, i.e. for the buffer layer 13a from 15 nm to 300 nm, for the hole transport layer 13b from 15 nm to 100 nm and for the organic light emitting layer 13c from 15 nm to 100 nm, respectively. However, thicknesses of the organic layer 13 and the layers forming it are determined so that their optical film thicknesses become the values explained later.

[0034] The semitransparent reflection layer 14 form a cathode electrode, and it is made of, for example, magnesium (Mg), silver (Ag) or their alloy. The semitransparent reflection layer 14 preferably has a thickness in the range from 5 nm to 50 nm.

[0035] The second electrode 15 is made of a material typically used as a transparent electrode, such as indium tin oxide (ITO) or an oxide of indium and zinc. Let the second electrode 15 have a thickness in the range from 30 nm to 1000 nm. A passivation film (not shown) made of a transparent dielectric overlies the second electrode 15. The transparent dielectric preferably has a refractive index approximately equal to that of the material forming the second electrode 15. As such material, silicon oxide (SiO_2), silicon nitride (SiN), or the like, can be used, and may be stacked to a thickness from 500 nm to 10000 nm, for example.

of the buffer layer 13a to be 240 nm in the organic EL device for emission of light in the red (R) region, 190 nm in the organic EL device for emission of light in the green (G) region, and 150 nm in the organic EL device for emission of light in the blue (B) region. Fig. 9 shows a simulation of spectrums to show the property as a simple filter of each organic layer having the same design as the comparative example. Spectrums shown in Fig. 8 are obtained by multiplying spectrums shown in Fig. 9 by spectrums of light extracted without multiple interference after being emitted in the organic light emitting layer 13c, that is, internal emission spectrums shown in Fig. 7.

[0047] As apparent from comparison of these figures, by determining the thickness of the organic layer 13 like the first embodiment, while subjecting the light h extracted from the organic EL device to multiple interference, its spectrum can maintain a certain width. Therefore, in the organic EL device according to the first embodiment, even when the view angle is offset, the shift amount of the wavelength λ can be limited to a small value, and color purity can be improved over a wider view angle range.

[0048] Fig. 10 shows dependency of the organic EL device (m=0) according to the first embodiment of the invention upon the view angle. Here is shown a light spectrum of the green (G) wavelength measured from angles of 0° (straight forward), 30° and 60° relative to the display plane. Fig. 11 is a graph that shows dependency of an organic EL device (m=1) as a comparative example upon the view angle.

[0049] As apparent through comparison of Figs. 10 and 11, in the organic EL device according to the first embodiment, the spectral peak does not shift substantially even when the view angle is offset by 30°, and even when the view angle is offset 60°, shifting of the spectral peak is within about 10 nm. In contrast, in the organic EL device taken as the comparative example, when the view angle is offset by 60°, the spectral peak shifts toward shorter wavelengths as much as 30 nm as shown in Fig. 11, and the color has changed. It has been confirmed from the comparison that the organic EL device according to the first embodiment can restrict shifting of the peak position of the spectrum of the extracted light h within a smaller value than the organic EL device as the comparative example even when the view angle is large.

[0050] Its reason is shown below. That is, when viewed obliquely from θ radians, Equation (6) can be rewritten as the following equation (8).

$$(2L)/\lambda' \times \cos\theta + \Phi/2(\Pi)=m \text{ (m is an integer)} \qquad (8)$$

[0051] If $\lambda'=\lambda+\Delta\lambda$ (λ is the peak wavelength of the filter property spectrum when the light emitting surface is viewed from the frontal direction), then $\Delta\lambda=(1-\cos\theta)\lambda$, the shift amount $\Delta\lambda$ of the peak of the filter property spectrum does not depend on the integer m defining the thickness of the organic layer for making up the cavity structure, but merely depends upon the view angle.

[0052] However, for a reason explained later, with a smaller m, the filter property spectrum is gentler and wider, i.e. broader, and the shifting amount of the peak of the spectrum of the extracted light is smaller. Therefore, in the organic EL device according to the first embodiment, color purity is improved in a wider view angle range. As a result, in a direct view type color display apparatus made by using this organic EL device, a sufficient color reproduction range can be ensured over wider view angles.

[0053] The phenomenon that the filter property spectrum becomes broader with a small m as explained above occurs by the following reason. In case the sum of the phase shifting values of reflected light generated in the anode electrode, i.e. first electrode 12, and the cathode electrode, i.e. semitransparent reflection layer 14 is Φ radians, L is the optical path length of the organic layer 13, and λ is the wavelength of light, if the phase delay per each multiple interference is 5,

$$\delta = 2\Pi \cdot 2L/\lambda + \Phi \qquad (9)$$

Here, a value of λ satisfying

$$\delta = 2\Pi \cdot m \text{ (m is an integer)} \qquad (10)$$

is the peak wavelength of the narrow-band-pass filter. When it is λ_{max}, then from Equations (9) and (10),

$$2L/\lambda_{max} + \Phi/2\Pi = m \text{ (m is an integer)} \qquad (11)$$

is obtained. As the optical path length L becomes smaller in Equation (9), the spectral width of the narrow-band-pass

$$(2L_3)/\lambda + \Phi/(2\Pi) = m1 + q \quad (15)$$

[0060] The cavity portion (i.e. second electrode 15) thus designed brings about multiple interference of light of a large number of wavelengths corresponding to the red (R), green (G) and blue (B) regions as shown in Fig. 14. Therefore, similarly to the second embodiment, optical path length L_3 of the cavity portion need not be determined for each color, and a common optical path length L_3 can be used in cavity portions in all organic EL devices corresponding to respective emission colors. In addition to that, as shown in Fig. 17, since the light extracted after multiple interference (light in the green (G) region in Fig. 17) results in having a plurality of fine peaks, the entire spectral width of the extracted light h becomes substantially wider. Therefore, similarly to the organic EL device according to the first embodiment, color purity can be improved over wider view angles. As a result, a direct-view color display apparatus made by using the organic EL device exhibits a sufficient color reproducibility in wide view angles.

[0061] The second and third embodiments are applicable either in combination with the first embodiment or independently. Configurations of the cavity portions explained as the second and third embodiments are also applicable to the cavity portion made up of the organic layer 13. However, cavity portions explained in the second and third embodiments will be optimum for use in a configuration using as the cavity portion the second electrode 15 having a relatively high freedom toward a thicker thickness. Additionally, structure of the cavity portion explained in the first embodiment is applicable also to cavity portion made up of the second electrode 15 (and the passivation film thereon).

[0062] Further, the foregoing embodiments are not limited to application to the top surface emission type organic EL device as shown in Fig. 4. For example, although the anode electrode explained as being the first electrode 12 made of a metal film having a high work function, it may be made in form of a two-layered structure stacking a transparent electrically conductive film on a dielectric multi-layered film or a reflection film of aluminum (Al), for example. In this case, this reflection film serves as the first electrode in the context of the invention. The transparent conductive film forms a part of the cavity portion.

[0063] Furthermore, the embodiments are applicable also to the structure as shown in Fig. 18, in which the first electrode 12 is a cathode electrode made of a light reflective material, the second electrode 15 is an anode electrode made of a transparent electrode, and the organic light emitting layer 13c, hole transport layer 13b and buffer layer 13c are stacked sequentially from the first electrode 12. In this case, the organic layer 13 and the second electrode 15 in combination are used as one cavity portion, and light generated in the organic light emitting layer 13c is reflected by the bottom end of the organic layer 13 (interface with the first electrode 12) and the top end of the second electrode 14 (interface with the atmospheric layer). Additionally, in this configuration, a semitransparent reflection layer (not shown) made of a material having a high work function, such as Pt, Au or Cr, can be used also in a configuration interposing it between the organic layer 13 and the second electrode 15. In this case, structure f the cavity portion will be the same as those of the first to third embodiments.

[0064] The invention is not limited to top surface emission type organic EL devices, but it is also applicable to transmission type organic EL devices using a transparent substrate 11, although not explained with reference to drawings. Further, it is also applicable to organic EL devices connected to a thin film transistor on the substrate 11.

(Fourth Embodiment)

[0065] Fig. 19 is a cross-sectional view that shows a central part of an organic EL device according to the fourth embodiment of the invention. The organic EL device shown in Fig. 19 includes a color filter in addition to the top surface emission type organic EL device according to the first embodiment shown in Fig. 4. More specifically, the first electrode 12 as the reflection layer, organic layer 13 and semitransparent reflection layer 14 make up the cavity structure, with the organic layer 13 as the cavity portion, and a color filter 20 is disposed on the semitransparent reflection layer 14 via the second electrode (transparent electrode) 15 and-the passivation film 16.

[0066] Let the color filter 20 be configured to transmit only light h near the peak wavelength λ of a spectrum to be extracted from the organic EL device. That is, a device for emitting light in the red (R) region has a color filter 20R that transmits light exclusively in the red (R) region, a device for emitting light in the green (G) region has a color filter 20G that transmits light exclusively in the green (G) region, and a device for emitting light in the blue (B) region has a color filter 20B that emits light exclusively in the blue (B) region.

[0067] Optical distance L of the cavity portion, which is the organic layer 13, is designed to be widest in the range bringing about multiple interference of light h near the peak wavelength λ of the spectrum to be extracted as already explained in the first embodiment. The wavelength range of the light h to be extracted from each organic layer 13 preferably coincides with the wavelength range in which each color filter 20 exhibits the highest transmittance.

[0068] In the organic EL device with this configuration, among external light H irradiated from the display surface side (surface nearer to the color filter 20), only light H_1 near the peak wavelength λ of the spectrum to be extracted

sion light similarly to the statement already made, and at the same time, the same effect as the second embodiment, i.e. common use of the optical path length L in cavity portions for different emission colors, can be also obtained.

[0080] Further, In organic EL devices additionally having the color filter to configurations explained in the third embodiments, contrast under external light can be improved significantly while ensuring a sufficient luminance of emission light similarly to the statement already made, and simultaneously, the same effect as the third embodiment, i.e. improvement of color purity in a wider view angle range, can be also obtained.

[0081] In case of using the organic EL devices according to the fourth embodiment also to an organic EL device configured to extract emission light through the substrate, the second electrode 32 of a transparent material, semi-transparent reflection layer 33 serving as the anode electrode as well, organic layer 34 made up of the buffer layer 34a, hole transport layer 34b and organic light emitting layer 34c, and first electrode 35 that is the cathode electrode serving as the reflection layer as well are sequentially stacked on the transparent substrate as shown in Fig. 23, for example, and an appropriately selected color filter 20 is disposed in combination on the other surface of the transparent substrate 31. Alternatively, the color filter 20 may be disposed between the transparent substrate 31 and the second electrode 32.

[0082] As explained above, according to the display device recited in claim 1 of the invention, the cavity structure is optimized such that, while maintaining a certain spectral width of light extracted from emission light, intensity of the peak wavelength λ of that light by multiple interference. Therefore, a display device limited in shifting of the wavelength λ of the extracted light and improved in color impurity can be obtained in a wider view angle range. As a result, a display apparatus using this display device can be enlarged in color reproduction range over a wide view angle range.

[0083] According to the display device recited in claim 2, emission light of each of wavelengths corresponding to red (R), green (G) and blue (B) can resonate in a common cavity portion. Therefore, optical path length need not specifically determined for each cavity portion of each display device for emission of a specific color, that is, a common optical path length L can be used in all cavity portions.

[0084] According to the display device recited in claim 3, it is possible to bring about multiple interference of emission light of a large number of peak wavelengths in respective red (R), green (G) and blue (B) regions in a common cavity portion. Therefore, optical path length need not specifically determined for each cavity portion of each display device for emission of a specific color, that is, a common optical path length L can be used in all cavity portions. Moreover, since each extracted light of each color result in having a plurality of fine peaks, entire spectral width of each light can be increased. Therefore, a display device limited in shifting of the wavelength λ of the extracted light and improved in color impurity can be obtained in a wider view angle range. As a result, a display apparatus using this display device can be enlarged in color reproduction range over a wide view angle range.

[0085] According to the display device recited in claim 4, because of the use of the combination of the cavity structure and the color filter, it is possible to prevent reflection of external light in all wavelength ranges containing light of a wavelength to be extracted without preventing radiation of part of emission light corresponding to the target wavelength. Therefore, contrast under external light can be improved significantly while keeping a sufficient luminance of emission light.

Claims

1. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that**:

   when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of part of light to be extracted, optical path length L of said cavity portion takes a positive minimum value in a range satisfying the equation:

   $$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

2. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that**:

   when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of

layer, **characterized in that:**

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\Pi) = m1 + 4$$

which is made by adding 4 to the integer m1 that is one of integers m satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

7. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that:**

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\Pi) = m1 + q$$

which is made by adding an integer not smaller than 10 to the integer m1 that is one of integers m satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

8. A display device having a light emitting layer between a first electrode and a second electrode such that at least one of said light emitting layer and one of said first electrodes and said second electrodes permitting light to be extracted therethrough functions as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that:**
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of part of light to be extracted, optical path length L of said cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

9. A display device having a light emitting layer between a first electrode and a second electrode such that at least one of said light emitting layer and one of said first electrodes and said second electrodes permitting light to be extracted therethrough functions as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that:**
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of

emitting layer, **characterized in that:**

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above one of said first electrode and said second electrode, through which light is to be extracted; and
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\Pi) = m1 + 4$$

which is made by adding 4 to the integer m1 that is one of integers m satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

14. A display device having a light emitting layer between a first electrode and a second electrode such that at least one of said light emitting layer and one of said first electrodes and said second electrodes permitting light to be extracted therethrough functions as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that:**

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above one of said first electrode and said second electrode, through which light is to be extracted; and
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\Pi) = m1 + q$$

which is made by adding an integer not smaller than 10 to the integer m1 that is one of integers m satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

15. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that:**
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of part of light to be extracted, optical path length L of said cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

16. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that:**

characterized in that:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\Pi) = m1 + 4$$

which is made by adding 4 to the integer m1 that is one of integers m satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

21. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that:**

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\Pi) = m1 + q$$

which is made by adding an integer not smaller than 10 to the integer m1 that is one of integers m satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

22. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that:**
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of part of light to be extracted, optical path length L of said cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

23. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that:**
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\Pi) = m1 + 4$$

which is made by adding 4 to the integer m1 that is one of integers m satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

28. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that**:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\Pi) = m1 + q$$

which is made by adding an integer not smaller than 10 to the integer m1 that is one of integers m satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

29. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said second electrode serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer,
characterized in that:
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of part of light to be extracted, optical path length L of said cavity portion takes a positive minimum value in a range satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

30. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said second electrode serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that**:
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\Pi) = m1 + 4$$

which is made by adding 4 to the integer m1 that is one of integers m satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

35. A display device having a first electrode, a light emitting layer and a second electrode of a transparent material sequentially stacked on a substrate and so configured that said second electrode serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that**:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and
when the phase shift produced in light generated in said light emitting layer when reflected by opposite ends of said cavity portion is Φ radians, L' is optical path length of said cavity portion, and λ is the peak wavelength of the spectrum of green light, optical path length L' of said cavity portion is determined to satisfy the equation:

$$(2L')/\lambda + \Phi/(2\Pi) = m1 + q$$

which is made by adding an integer not smaller than 10 to the integer m1 that is one of integers m satisfying the equation:

$$(2L)/\lambda + \Phi/(2\Pi) = m \text{ (m is an integer)}$$

with which L takes a positive minimum value.

36. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that**:
when optical path length of said cavity portion is L, said optical path length L is determined so determined that difference between the peak wavelength of the spectrum of light to be extracted upon a change in view angle and the peak wavelength of the internal emission spectrum is limited within one half of the half-width of said internal emission spectrum.

37. A display device having a light emitting layer interposed between a first electrode of a light reflective material and a second electrode of a transparent material and so configured that at least one of said second electrode and said light emitting layer serves as a cavity portion of a cavity structure for resonating light emitted in said light emitting layer, **characterized in that**:

a color filter for transmitting light which resonates in said cavity portion and is to be extracted through said second electrode is provided above said second electrode; and
when optical path length of said cavity portion is L, said optical path length L is determined so determined that difference between the peak wavelength of the spectrum of light to be extracted upon a change in view angle and the peak wavelength of the internal emission spectrum is limited within one half of the half-width of said internal emission spectrum.

Fig. 3

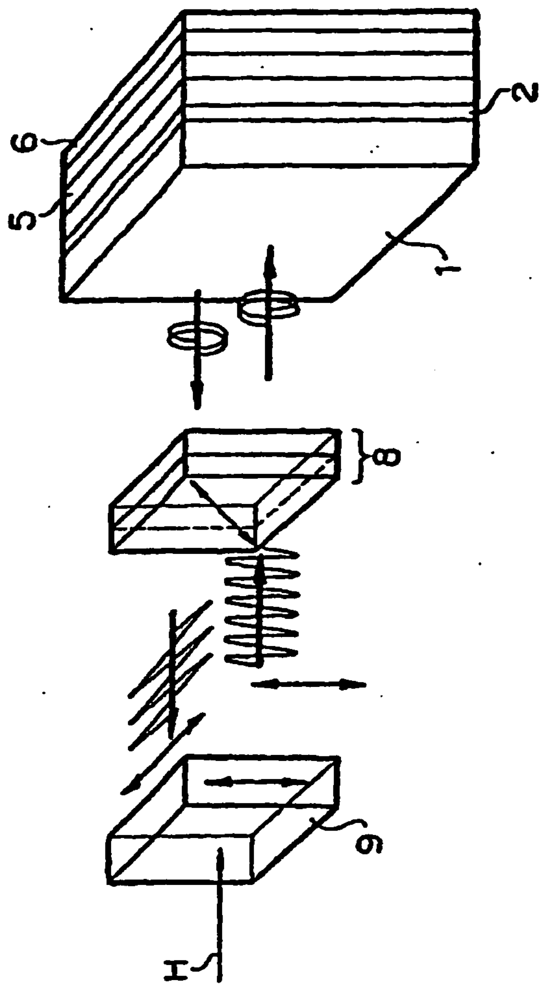


Fig. 5

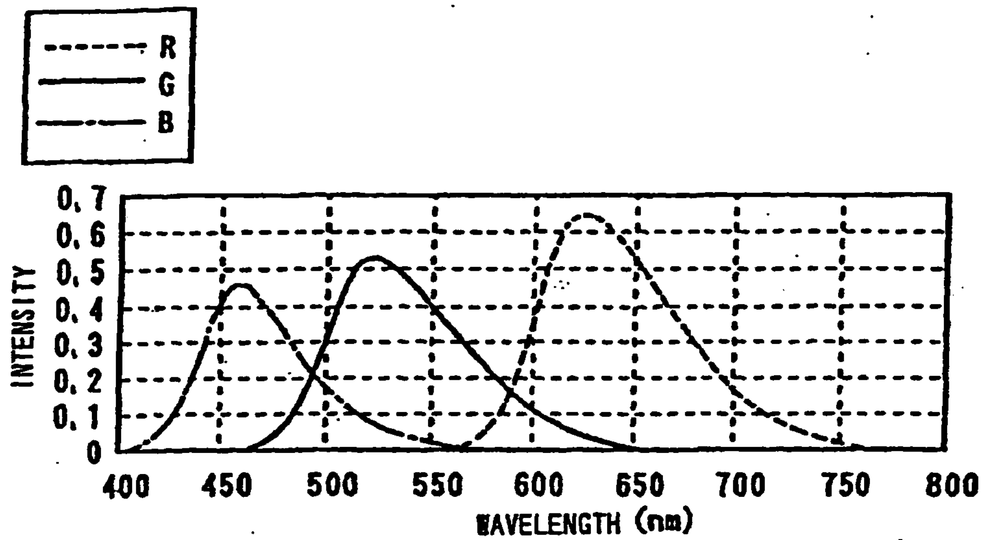

R
G
B
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
INTENSITY
400
450
500
550
600
650
700
750
800
WAVELENGTH (nm)

Fig. 6

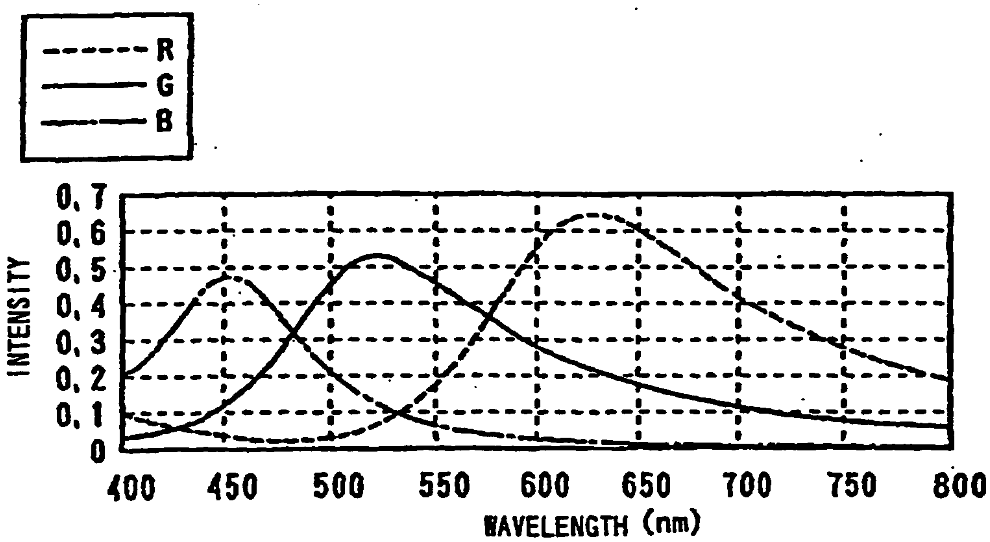

R
G
B
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
INTENSITY
400
450
500
550
600
650
700
750
800
WAVELENGTH (nm)

Fig. 9

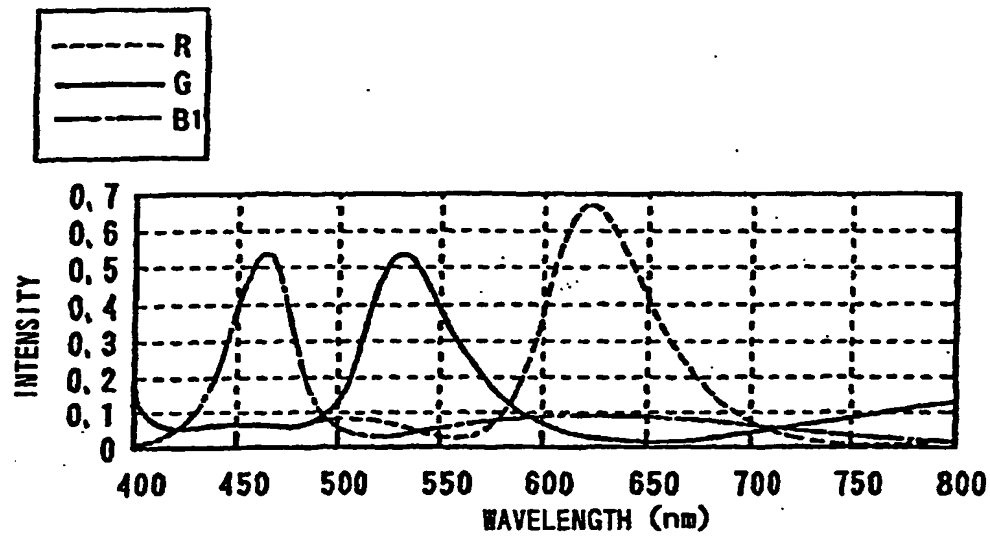

R
G
B1
0, 7
0, 6
0, 5
0, 4
0, 3
0, 2
0, 1
0
INTENSITY
400
450
500
550
600
650
700
750
800
WAVELENGTH (nm)

Fig. 10

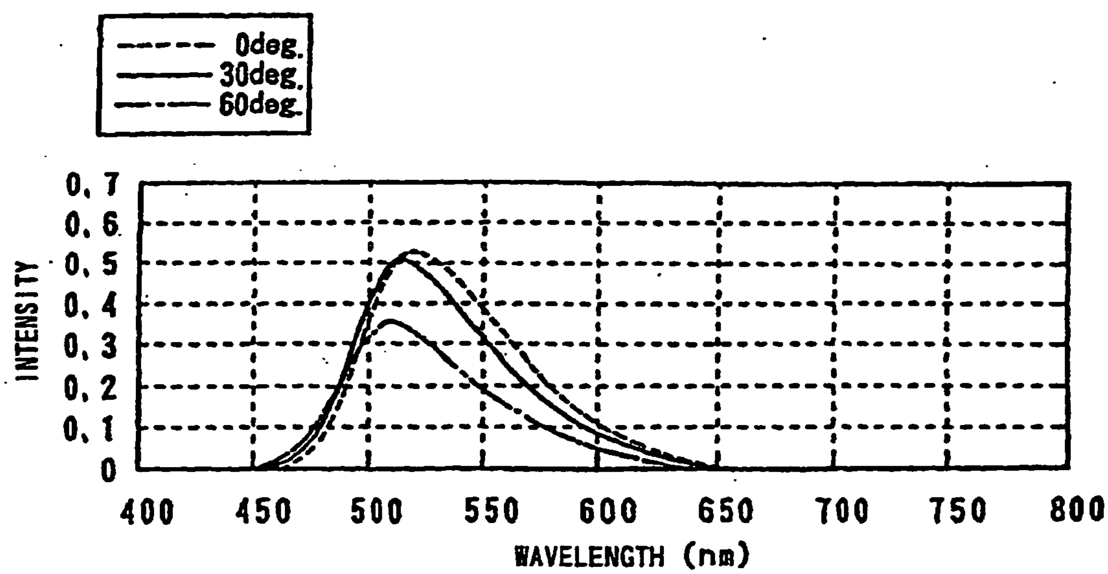

0deg.
30deg.
60deg.
0, 7
0, 6
0, 5
0, 4
0, 3
0, 2
0, 1
0
INTENSITY
400
450
500
550
600
650
700
750
800
WAVELENGTH (nm)

Fig. 12

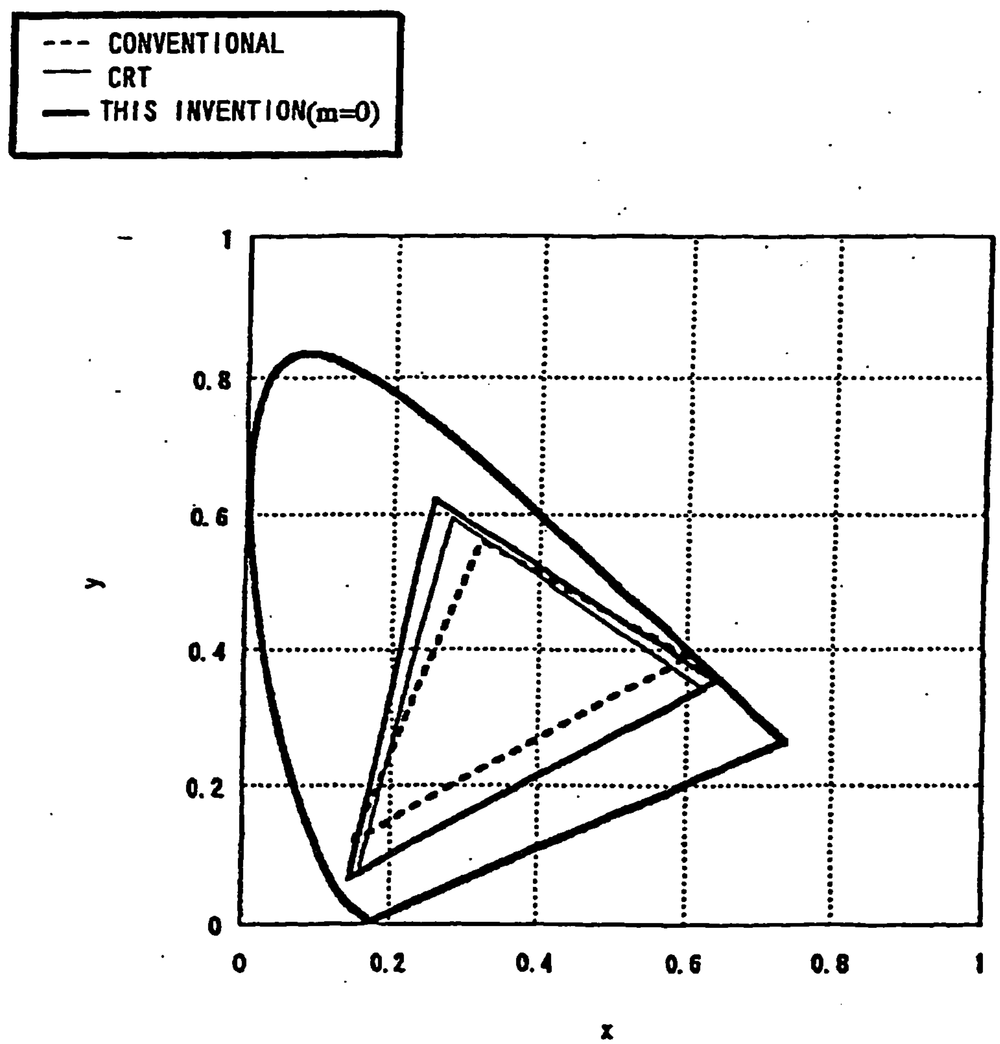

CONVENTIONAL
CRT
THIS INVENTION(m=0)
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
y
x

Fig. 14

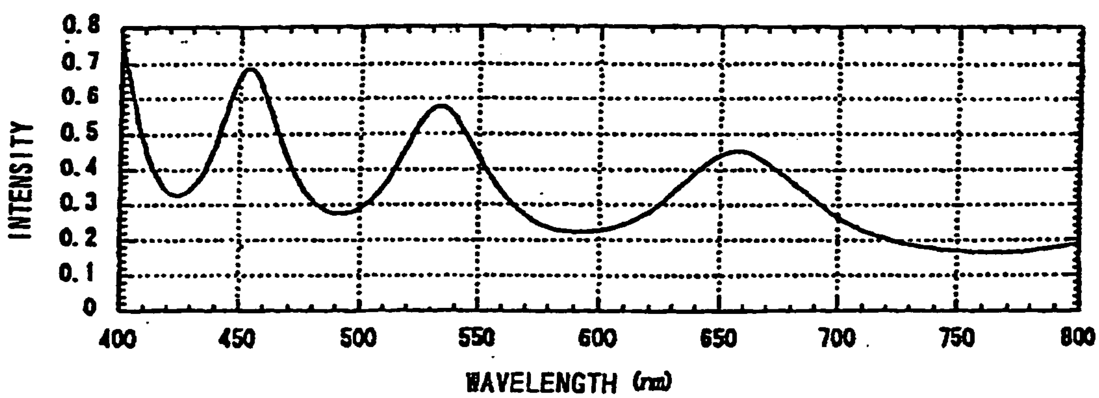

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
INTENSITY
400
450
500
550
600
650
700
750
800
WAVELENGTH (nm)

Fig. 16

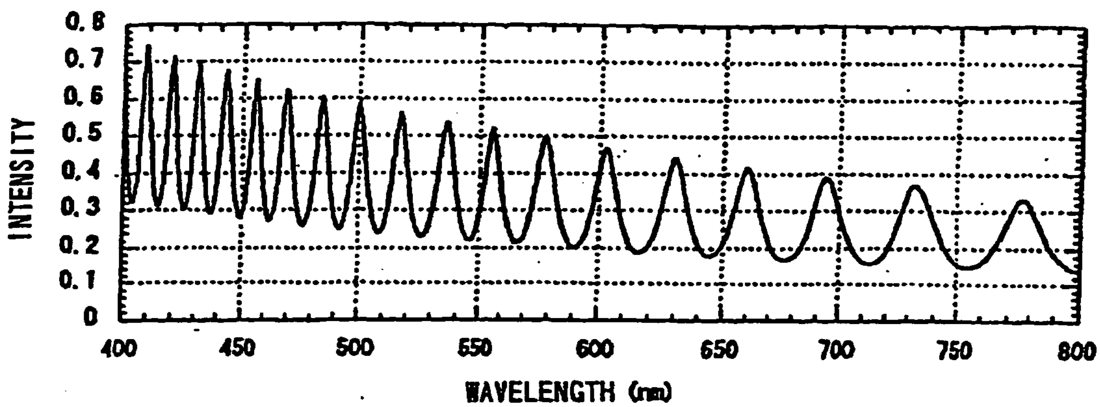

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
INTENSITY
400
450
500
550
600
650
700
750
800
WAVELENGTH (nm)

Fig. 17

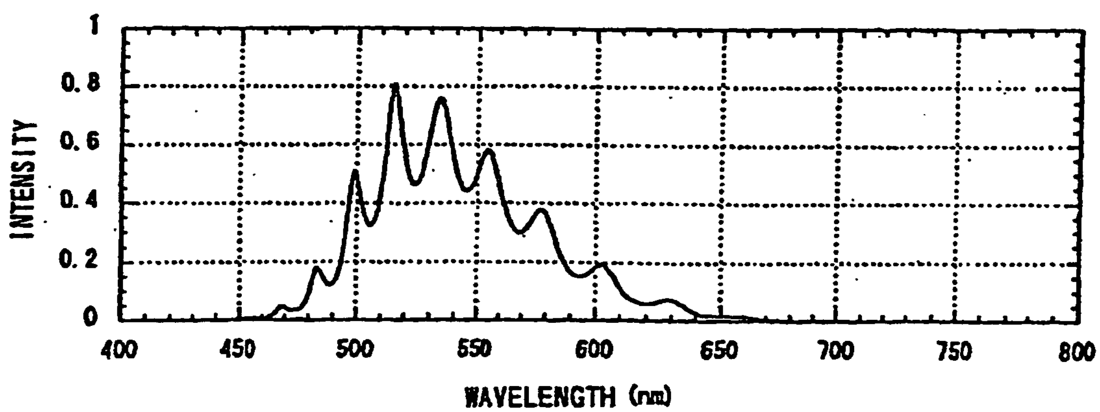

1
0.8
0.6
0.4
0.2
0
INTENSITY
400
450
500
550
600
650
700
750
800
WAVELENGTH (nm)

Fig. 19

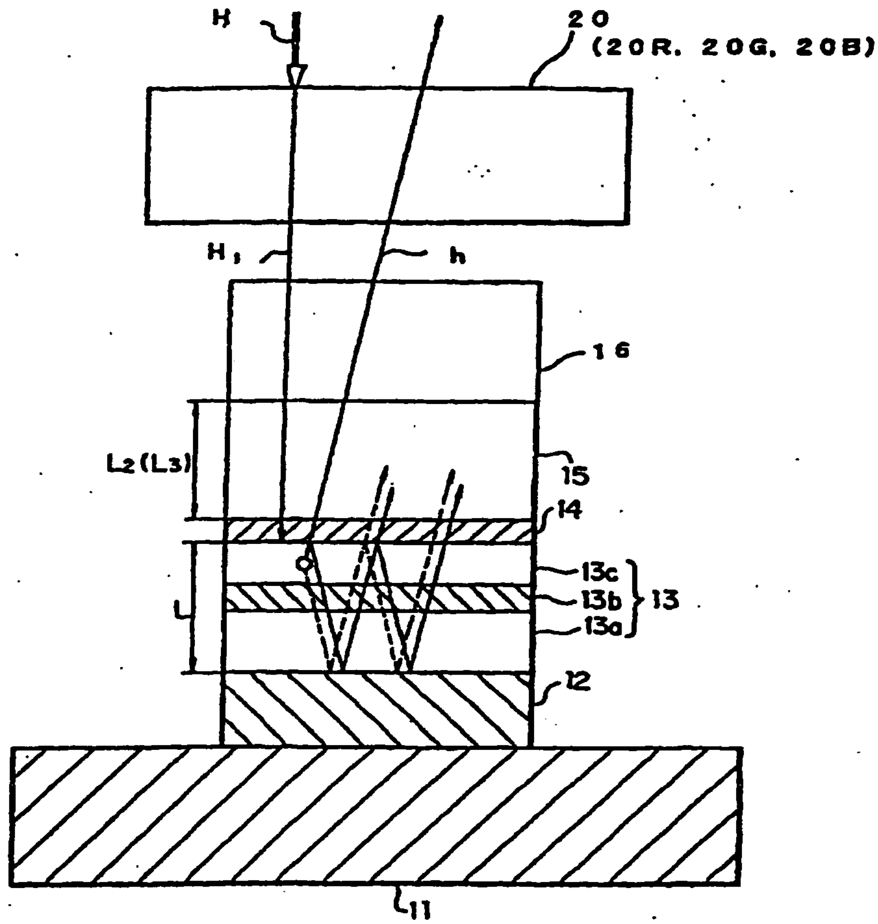
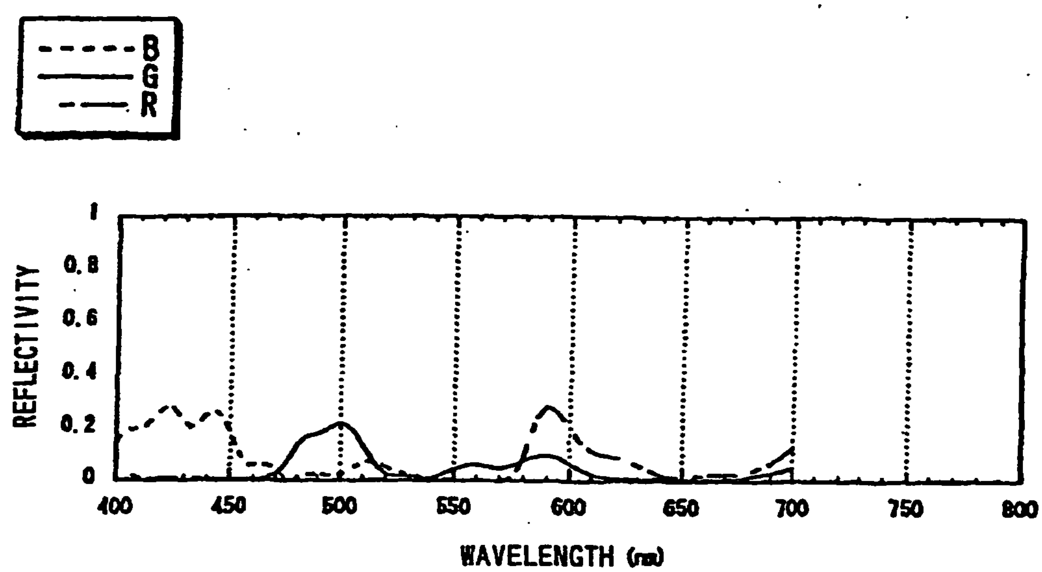


Fig. 22


B
G
R
1
0.8
0.6
0.4
0.2
0
400
450
500
550
600
650
700
750
800
REFLECTIVITY
WAVELENGTH (nm)

DESCRIPTION OF REFERENCE NUMERALS

12, 35	FIRST ELECTRODE
13, 34	ORGANIC LAYER
13c, 34c	ORGANIC LIGHT EMITTING LAYER
14, 33	SEMITRANSPARENT REFLECTION LAYER
15, 32	SECOND ELECTRODE
20	COLOR FILTER

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP00/08233

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 5-343183, A (Hitachi, Ltd.), 24 December, 1993 (24.12.93) (Family: none)	1-37
A	JP, 7-240277, A (Idemitsu Kosan Co., Ltd.), 12 September, 1995 (12.09.95) & US, 5891554, A & US, 6124024, A	1-37
A	JP, 8-213174, A (Hitachi, Ltd.), 20 August, 1996 (20.08.96) & WO, 94/07344, A1	1-37
A	Transactions C-II of the Institute of Electronics, Information and Communication Engineers, Vol.J77-C-II, No.10, pp.437-443(1994), Takahiro NAKAYAMA et al., "Bishoukou Kyoushinki Kouzou wo Rirou shita Yuki Hakkkou Soshi ni yoru Tashoku Hyouji no Kentou"	1-37
A	Appl. Phys. Lett, Vol.64, No.19 (1994) pp.2486-2488 "Microcavity effects in organic semiconductors"	1-37
A	J.Optical Society of America B, Vol.17, No.1 (2000) pp. 114-119 "Semitransparent metal or distributed Bragg reflector for wide-viewing-angle organic light-emitting-diode microcavities"	1-37
A	Appl. Phys. Lett., Vol.65, No.18(1994) pp.2308-2310 "Color variation with electroluminescet organic semiconductors in multimode resonant cavities"	1-37

Form PCT/ISA/210 (continuation of second sheet) (July 1992)